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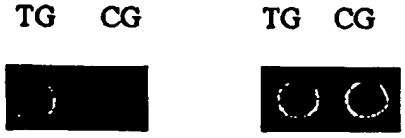
(54) Title: DIAGNOSIS OF DISEASES ASSOCIATED WITH DNA REPLICATION

(57) Abstract: The present invention relates to the chemically modified genomic sequences of genes associated with DNA replication, to oligonucleotides and/or PNA-oligomers for detecting the cytosine methylation state of genes associated with DNA replication which are directed against the sequence, as well as to a method for ascertaining genetic and/or epigenetic parameters of genes associated with DNA replication.




Sample I Sample II

WO 01/77377 A2

# Diagnosis of Diseases Associated with DNA replication

## Field of the Invention

The levels of observation that have been well studied by the methodological developments of recent years in molecular biology, are the genes themselves, the translation of these genes into RNA, and the resulting proteins. The question of which gene is switched on at which point in the course of the development of an individual, and how the activation and inhibition of specific genes in specific cells and tissues are controlled is correlatable to the degree and character of the methylation of the genes or of the genome. In this respect, pathogenic conditions may manifest themselves in a changed methylation pattern of individual genes or of the genome.

The present invention relates to nucleic acids, oligonucleotides, PNA-oligomers and to a method for the diagnosis and/or therapy of diseases which have a connection with the genetic and/or epigenetic parameters of genes associated with DNA replication and, in particular, with the methylation status thereof.

## Prior Art

The replication of double stranded genomic DNA is a complex activity. It is carried out in three key stages, initiation, elongation and termination. Each stage involves specific protein and enzyme complexes. During initiation, the double helix is temporarily separated and stabilized into two single strands, each of which acts as a template for the replication of the DNA from the replication fork. Separation of the two strands is carried out by a helicase, and stabilisation of the strands is achieved using a single stranded binding protein. Replication of the DNA is then carried out by a polymerase after synthesis of a short 'primer' sequence. Replication is carried out in a semi-discontinuous fashion. The leading strand is continuously synthesised in the 5' to 3' direction. Whereas replication of the lagging strand, in the 3' to 5' direction is made by the synthesis of short fragments in the 5' to 3' direction. In the final stage, replication is terminated, and the lagging strand complementary DNA fragments are ligated into a continuous strand.

A further overview of the components of the DNA replication system is available from references such as Alberts *et. al.* 'Molecular Biology of the cell' Garland Publishing.

Disruptions to the ordered replication of DNA may impact on a wide variety of disease phenotypes. These range from chromosomal disorders to disorders at a molecular level. Malfunctions in the specific genes involved in DNA replication have been implicated in several disease phenotypes, including, but not limited to cancer:

- Ataxia-telangiectasia; Meyn MS. 'Ataxia-telangiectasia, cancer and the pathobiology of the ATM gene'. Clin Genet. 1999 May;55(5):289-304.

- ATR-X; Wada T. 'Molecular genetic study of japanese patients with X-linked alpha-thalassemia/mental retardation syndrome'. Am J Med Genet. 2000 Sep 18;94(3):242-8.

- Bloom's syndrome; German J. 'Bloom's syndrome'. Dermatol Clin. 1995 Jan;13(1):7-18.

- Cancer; Sturgis *et. al.* 'XPD/ERCC2 polymorphisms and risk of head and neck cancer: a case-control analysis.' Carcinogenesis. 2000 Dec;21(12):2219-23.

- Neurological disorders; Hermon *et. al.* 'Expression of DNA excision-repair-cross-complementing proteins p80 and p89 in brain of patients with Down Syndrome and Alzheimer's disease.' Neurosci Lett. 1998 Jul 17;251(1):45-8.

The diversity of components involved in DNA replication provides an alternative target for therapies and diagnosis for diseases. In particular this may be relevant to diseases where current therapies may have unwanted side effects or fail to provide effective treatment. For cancer patients such methods constitute a considerable advantage over conventional methods such as chemotherapy, which with their massive side effects, sometimes result in unacceptable morbidity or lead up to the death of the patient. In practice, the unwanted side effects associated with cancer therapies frequently limit the treatment which could help a patient.

A global analysis of the status of DNA replication mechanisms would provide a basis for the development of appropriate and specific therapies for diseases associated with DNA replication. The current state of the art is such that the analysis may be carried out in a gene specific manner based on the results of gene expression, e.g. DNA micro array analysis of mRNA

expression or proteomic analysis. The next step would then be to look at the causal factors involved at earlier stages in the regulatory mechanisms controlling DNA replication. DNA methylation provides such a novel level of information at which to analyse the genome.

5-methylcytosine is the most frequent covalent base modification in the DNA of eukaryotic cells. It plays a role, for example, in the regulation of the transcription, in genetic imprinting, and in tumorigenesis. Therefore, the identification of 5-methylcytosine as a component of genetic information is of considerable interest. However, 5-methylcytosine positions cannot be identified by sequencing since 5-methylcytosine has the same base pairing behaviour as cytosine. Moreover, the epigenetic information carried by 5-methylcytosine is completely lost during PCR amplification.

A relatively new and currently the most frequently used method for analyzing DNA for 5-methylcytosine is based upon the specific reaction of bisulfite with cytosine which, upon subsequent alkaline hydrolysis, is converted to uracil which corresponds to thymidine in its base pairing behavior. However, 5-methylcytosine remains unmodified under these conditions. Consequently, the original DNA is converted in such a manner that methylcytosine, which originally could not be distinguished from cytosine by its hybridization behavior, can now be detected as the only remaining cytosine using "normal" molecular biological techniques, for example, by amplification and hybridization or sequencing. All of these techniques are based on base pairing which can now be fully exploited. In terms of sensitivity, the prior art is defined by a method which encloses the DNA to be analyzed in an agarose matrix, thus preventing the diffusion and renaturation of the DNA (bisulfite only reacts with single-stranded DNA), and which replaces all precipitation and purification steps with fast dialysis (Olek A, Oswald J, Walter J. A modified and improved method for bisulphite based cytosine methylation analysis. Nucleic Acids Res. 1996 Dec 15;24(24):5064-6). Using this method, it is possible to analyze individual cells, which illustrates the potential of the method. However, currently only individual regions of a length of up to approximately 3000 base pairs are analyzed, a global analysis of cells for thousands of possible methylation events is not possible. However, this method cannot reliably analyze very small fragments from small sample quantities either. These are lost through the matrix in spite of the diffusion protection.

An overview of the further known methods of detecting 5-methylcytosine may be gathered from the following review article: Rein, T., DePamphilis, M. L., Zorbas, H., Nucleic Acids Res. 1998, 26, 2255.

To date, barring few exceptions (e.g., Zeschnigk M, Lich C, Buiting K, Doerfler W, Horsthemke B. A single-tube PCR test for the diagnosis of Angelman and Prader-Willi syndrome based on allelic methylation differences at the SNRPN locus. Eur J Hum Genet. 1997 Mar-Apr;5(2):94-8) the bisulfite technique is only used in research. Always, however, short, specific fragments of a known gene are amplified subsequent to a bisulfite treatment and either completely sequenced (Olek A, Walter J. The pre-implantation ontogeny of the H19 methylation imprint. Nat Genet. 1997 Nov;17(3):275-6) or individual cytosine positions are detected by a primer extension reaction (Gonzalgo ML, Jones PA. Rapid quantitation of methylation differences at specific sites using methylation-sensitive single nucleotide primer extension (Ms-SNuPE). Nucleic Acids Res. 1997 Jun 15;25(12):2529-31, WO 95/00669) or by enzymatic digestion (Xiong Z, Laird PW. COBRA: a sensitive and quantitative DNA methylation assay. Nucleic Acids Res. 1997 Jun 15;25(12):2532-4). In addition, detection by hybridization has also been described (Olek et al., WO 99/28498).

Further publications dealing with the use of the bisulfite technique for methylation detection in individual genes are: Grigg G, Clark S. Sequencing 5-methylcytosine residues in genomic DNA. Bioessays. 1994 Jun;16(6):431-6, 431; Zeschnigk M, Schmitz B, Dittrich B, Buiting K, Horsthemke B, Doerfler W. Imprinted segments in the human genome: different DNA methylation patterns in the Prader-Willi/Angelman syndrome region as determined by the genomic sequencing method. Hum Mol Genet. 1997 Mar;6(3):387-95; Feil R, Charlton J, Bird AP, Walter J, Reik W. Methylation analysis on individual chromosomes: improved protocol for bisulphite genomic sequencing. Nucleic Acids Res. 1994 Feb 25;22(4):695-6; Martin V, Ribieras S, Song-Wang X, Rio MC, Dante R. Genomic sequencing indicates a correlation between DNA hypomethylation in the 5' region of the pS2 gene and its expression in human breast cancer cell lines. Gene. 1995 May 19;157(1-2):261-4; WO 97/46705, WO 95/15373 and WO 97/45560.

An overview of the Prior Art in oligomer array manufacturing can be gathered from a special edition of Nature Genetics (Nature Genetics Supplement, Volume 21, January 1999), published in January 1999, and from the literature cited therein.

Fluorescently labelled probes are often used for the scanning of immobilised DNA arrays. The simple attachment of Cy3 and Cy5 dyes to the 5'-OH of the specific probe are particularly suitable for fluorescence labels. The detection of the fluorescence of the hybridized probes may be carried out, for example via a confocal microscope. Cy3 and Cy5 dyes, besides many others, are commercially available.

Matrix Assisted Laser Desorption Ionization Mass Spectrometry (MALDI-TOF) is a very efficient development for the analysis of biomolecules (Karas M, Hillenkamp F. Laser desorption ionization of proteins with molecular masses exceeding 10,000 daltons. Anal Chem. 1988 Oct 15;60(20):2299-301). An analyte is embedded in a light-absorbing matrix. The matrix is evaporated by a short laser pulse thus transporting the analyte molecule into the vapor phase in an unfragmented manner. The analyte is ionized by collisions with matrix molecules. An applied voltage accelerates the ions into a field-free flight tube. Due to their different masses, the ions are accelerated at different rates. Smaller ions reach the detector sooner than bigger ones.

MALDI-TOF spectrometry is excellently suited to the analysis of peptides and proteins. The analysis of nucleic acids is somewhat more difficult (Gut I G, Beck S. DNA and Matrix Assisted Laser Desorption Ionization Mass Spectrometry. Current Innovations and Future Trends. 1995, 1; 147-57). The sensitivity to nucleic acids is approximately 100 times worse than to peptides and decreases disproportionally with increasing fragment size. For nucleic acids having a multiply negatively charged backbone, the ionization process via the matrix is considerably less efficient. In MALDI-TOF spectrometry, the selection of the matrix plays an eminently important role. For the desorption of peptides, several very efficient matrixes have been found which produce a very fine crystallization. There are now several responsive matrixes for DNA, however, the difference in sensitivity has not been reduced. The difference in sensitivity can be reduced by chemically modifying the DNA in such a manner that it becomes more similar to a peptide. Phosphorothioate nucleic acids in which the usual phosphates of the backbone are substituted with thiophosphates can be converted into a charge-

neutral DNA using simple alkylation chemistry (Gut IG, Beck S. A procedure for selective DNA alkylation and detection by mass spectrometry. Nucleic Acids Res. 1995 Apr 25;23(8):1367-73). The coupling of a charge tag to this modified DNA results in an increase in sensitivity to the same level as that found for peptides. A further advantage of charge tagging is the increased stability of the analysis against impurities which make the detection of unmodified substrates considerably more difficult.

Genomic DNA is obtained from DNA of cell, tissue or other test samples using standard methods. This standard methodology is found in references such as Fritsch and Maniatis eds., Molecular Cloning: A Laboratory Manual, 1989.

**Description**

The object of the present invention is to provide the chemically modified DNA of genes associated with DNA replication, as well as oligonucleotides and/or PNA-oligomers for detecting cytosine methylations, as well as a method which is particularly suitable for the diagnosis and/or therapy of genetic and epigenetic parameters of genes associated with DNA replication. The present invention is based on the discovery that genetic and epigenetic parameters and, in particular, the cytosine methylation pattern of genes associated with DNA replication are particularly suitable for the diagnosis and/or therapy of diseases associated with DNA replication.

This objective is achieved according to the present invention using a nucleic acid containing a sequence of at least 18 bases in length of the chemically pretreated DNA of genes associated with DNA replication according to one of Seq. ID No.1 through Seq. ID No.94 and sequences complementary thereto and/or a sequence of a chemically pretreated DNA of genes according to table 1 and sequences complementary thereto. In the table, after the listed gene designations, the respective data bank numbers (accession numbers) are specified which define the appertaining gene sequences as unique. GenBank was used as the underlying data bank, which is located at the National Institute of Health, internet address www.ncbi.nlm.nih.gov.

The chemically modified nucleic acid could heretofore not be connected with the ascertainment of genetic and epigenetic parameters.

The object of the present invention is further achieved by an oligonucleotide or oligomer for detecting the cytosine methylation state in chemically pretreated DNA, containing at least one base sequence having a length of at least 13 nucleotides which hybridizes to a chemically pretreated DNA of genes associated with DNA replication according to Seq. ID No.1 through Seq. ID No.94 and sequences complementary thereto and/or a sequence of a chemically pretreated DNA of genes according to table 1 and sequences complementary thereto. The oligomer probes according to the present invention constitute important and effective tools which, for the first time, make it possible to ascertain the genetic and epigenetic parameters of genes associated with DNA replication. The base sequence of the oligomers preferably contains at least one CpG dinucleotide. The probes may also exist in the form of a PNA (peptide nucleic acid) which has particularly preferred pairing properties. Particularly preferred are oligonucleotides according to the present invention in which the cytosine of the CpG dinucleotide is the $5^{th}$ - $9^{th}$ nucleotide from the 5'-end of the 13-mer; in the case of PNA-oligomers, it is preferred for the cytosine of the CpG dinucleotide to be the $4^{th}$ - $6^{th}$ nucleotide from the 5'-end of the 9-mer.

The oligomers according to the present invention are normally used in so called "sets" which contain at least one oligomer for each of the CpG dinucleotides of the sequences of Seq. ID No.1 through Seq. ID No.94 and sequences complementary thereto and/or a sequence of a chemically pretreated DNA of genes according to table 1 and sequences complementary thereto. Preferred is a set which contains at least one oligomer for each of the CpG dinucleotides from one of Seq. ID No.1 through Seq. ID No.94 and sequences complementary thereto and/or a sequence of a chemically pretreated DNA of genes according to table 1 and sequences complementary thereto.

Moreover, the present invention makes available a set of at least two oligonucleotides which can be used as so-called "primer oligonucleotides" for amplifying DNA sequences of one of Seq. ID No.1 through Seq. ID No.94 and sequences complementary thereto and/or a sequence of a chemically pretreated DNA of genes according to table 1 and sequences complementary thereto, or segments thereof.

In the case of the sets of oligonucleotides according to the present invention, it is preferred that at least one oligonucleotide is bound to a solid phase.

The present invention moreover relates to a set of at least 10 n (oligonucleotides and/or PNA-oligomers) used for detecting the cytosine methylation state in chemically pretreated genomic DNA (Seq. ID No.1 through Seq. ID No.94 and sequences complementary thereto and/or a sequence of a chemically pretreated DNA of genes according to table 1 and sequences complementary thereto). These probes enable diagnosis and/or therapy of genetic and epigenetic parameters of genes associated with DNA replication. The set of oligomers may also be used for detecting single nucleotide polymorphisms (SNPs) in the chemically pretreated DNA of genes associated with DNA replication according to one of Seq. ID No.1 through Seq. ID No.94 and sequences complementary thereto and/or a sequence of a chemically pretreated DNA of genes according to table 1 and sequences complementary thereto.

According to the present invention, it is preferred that an arrangement of different oligonucleotides and/or PNA-oligomers (a so-called "array") made available by the present invention is present in a manner that it is likewise bound to a solid phase. This array of different oligonucleotide- and/or PNA-oligomer sequences can be characterized in that it is arranged on the solid phase in the form of a rectangular or hexagonal lattice. The solid phase surface is preferably composed of silicon, glass, polystyrene, aluminium, steel, iron, copper, nickel, silver, or gold. However, nitrocellulose as well as plastics such as nylon which can exist in the form of pellets or also as resin matrices are possible as well.

Therefore, a further subject matter of the present invention is a method for manufacturing an array fixed to a carrier material for analysis in connection with diseases associated with DNA replication in which method at least one oligomer according to the present invention is coupled to a solid phase. Methods for manufacturing such arrays are known, for example, from US Patent 5,744,305 by means of solid-phase chemistry and photolabile protecting groups.

A further subject matter of the present invention relates to a DNA chip for the analysis of diseases associated with DNA replication which contains at least one nucleic acid according to the present invention. DNA chips are known, for example, for US Patent 5,837,832.

Moreover, a subject matter of the present invention is a kit which may be composed, for example, of a bisulfite-containing reagent, a set of primer oligonucleotides containing at least

two oligonucleotides whose sequences in each case correspond or are complementary to an 18 base long segment of the base sequences specified in the appendix (Seq. ID No.1 through Seq. ID No.94 and sequences complementary thereto and/or a sequence of a chemically pretreated DNA of genes according to table 1 and sequences complementary thereto), oligonucleotides and/or PNA-oligomers as well as instructions for carrying out and evaluating the described method. However, a kit along the lines of the present invention can also contain only part of the aforementioned components.

The present invention also makes available a method for ascertaining genetic and/or epigenetic parameters of genes associated with the cycle cell by analyzing cytosine methylations and single nucleotide polymorphisms, including the following steps:

In the first step of the method, a genomic DNA sample is chemically treated in such a manner that cytosine bases which are unmethylated at the 5'-position are converted to uracil, thymine, or another base which is dissimilar to cytosine in terms of hybridization behavior. This will be understood as 'chemical pretreatment' hereinafter.

The genomic DNA to be analyzed is preferably obtained form usual sources of DNA such as cells or cell components, for example, cell lines, biopsies, blood, sputum, stool, urine, cerebral-spinal fluid, tissue embedded in paraffin such as tissue from eyes, intestine, kidney, brain, heart, prostate, lung, breast or liver, histologic object slides, or combinations thereof.

The above described treatment of genomic DNA is preferably carried out with bisulfite (hydrogen sulfite, disulfite) and subsequent alkaline hydrolysis which results in a conversion of non-methylated cytosine nucleobases to uracil or to another base which is dissimilar to cytosine in terms of base pairing behaviour.

Fragments of the chemically pretreated DNA are amplified, using sets of primer oligonucleotides according to the present invention, and a, preferably heat-stable polymerase. Because of statistical and practical considerations, preferably more than ten different fragments having a length of 100 - 2000 base pairs are amplified. The amplification of several DNA segments can be carried out simultaneously in one and the same reaction vessel. Usually, the amplification is carried out by means of a polymerase chain reaction (PCR).

In a preferred embodiment of the method, the set of primer oligonucleotides includes at least two olignonucleotides whose sequences are each reverse complementary or identical to an at least 18 base-pair long segment of the base sequences specified in the appendix (Seq. ID No.1 through Seq. ID No.94 and sequences complementary thereto and/or a sequence of a chemically pretreated DNA of genes according to table 1 and sequences complementary thereto). The primer oligonucleotides are preferably characterized in that they do not contain any CpG dinucleotides.

According to the present invention, it is preferred that at least one primer oligonucleotide is bonded to a solid phase during amplification. The different oligonucleotide and/or PNA-oligomer sequences can be arranged on a plane solid phase in the form of a rectangular or hexagonal lattice, the solid phase surface preferably being composed of silicon, glass, polystyrene, aluminium, steel, iron, copper, nickel, silver, or gold, it being possible for other materials such as nitrocellulose or plastics to be used as well.

The fragments obtained by means of the amplification can carry a directly or indirectly detectable label. Preferred are labels in the form of fluorescence labels, radionuclides, or detachable molecule fragments having a typical mass which can be detected in a mass spectrometer, it being preferred that the fragments that are produced have a single positive or negative net charge for better detectability in the mass spectrometer. The detection may be carried out and visualised by means of matrix assisted laser desorption/ionization mass spectrometry (MALDI) or using electron spray mass spectrometry (ESI).

The amplificates obtained in the second step of the method are subsequently hybridized to an array or a set of oligonucleotides and/or PNA probes. In this context, the hybridization takes place in the manner described in the following. The set of probes used during the hybridization is preferably composed of at least 10 oligonucleotides or PNA-oligomers. In the process, the amplificates serve as probes which hybridize to oligonucleotides previously bonded to a solid phase. The non-hybridized fragments are subsequently removed. Said oligonucleotides contain at least one base sequence having a length of 13 nucleotides which is reverse complementary or identical to a segment of the base sequences specified in the appendix, the segment containing at least one CpG dinucleotide. The cytosine of the CpG dinucleotide is

the 5th to 9th nucleotide from the 5'-end of the 13-mer. One oligonucleotide exists for each CpG dinucleotide. Said PNA-oligomers contain at least one base sequence having a length of 9 nucleotides which is reverse complementary or identical to a segment of the base sequences specified in the appendix, the segment containing at least one CpG dinucleotide. The cytosine of the CpG dinucleotide is the 4th to 6th nucleotide seen from the 5'-end of the 9-mer. One oligonucleotide exists for each CpG dinucleotide.

In the fourth step of the method, the non-hybridized amplificates are removed.

In the final step of the method, the hybridized amplificates are detected. In this context, it is preferred that labels attached to the amplificates are identifiable at each position of the solid phase at which an oligonucleotide sequence is located.

According to the present invention, it is preferred that the labels of the amplificates are fluorescence labels, radionuclides, or detachable molecule fragments having a typical mass which can be detected in a mass spectrometer. The mass spectrometer is preferred for the detection of the amplificates, fragments of the amplificates or of probes which are complementary to the amplificates, it being possible for the detection to be carried out and visualized by means of matrix assisted laser desorption/ionization mass spectrometry (MALDI) or using electron spray mass spectrometry (ESI).

The produced fragments may have a single positive or negative net charge for better detectability in the mass spectrometer. The aforementioned method is preferably used for ascertaining genetic and/or epigenetic parameters of genes associated with DNA replication.

The oligomers according to the present invention or arrays thereof as well as a kit according to the present invention are intended to be used for the diagnosis and/or therapy of diseases associated with DNA replication by analyzing methylation patterns of genes associated with DNA replication. According to the present invention, the method is preferably used for the diagnosis and/or therapy of important genetic and/or epigenetic parameters within genes associated with DNA replication.

The method according to the present invention is used, for example, for the diagnosis and/or therapy of Ataxia telangiectasia, ATR-X, Bloom's syndrome, neurological disorders, solid tumors and cancer.

The nucleic acids according to the present invention of Seq. ID No.1 through Seq. ID No.94 and sequences complementary thereto and/or a sequence of a chemically pretreated DNA of genes according to table 1 and sequences complementary thereto can be used for the diagnosis and/or therapy of genetic and/or epigenetic parameters of genes associated with DNA replication.

The present invention moreover relates to a method for manufacturing a diagnostic agent and/or therapeutic agent for the diagnosis and/or therapy of diseases associated with DNA replication by analyzing methylation patterns of genes associated with DNA replication, the diagnostic agent and/or therapeutic agent being characterized in that at least one nucleic acid according to the present invention is used for manufacturing it, possibly together with suitable additives and auxiliary agents.

A further subject matter of the present invention relates to a diagnostic agent and/or therapeutic agent for diseases associated with DNA replication by analyzing methylation patterns of genes associated with DNA replication, the diagnostic agent and/or therapeutic agent containing at least one nucleic acid according to the present invention, possibly together with suitable additives and auxiliary agents.

The present invention moreover relates to the diagnosis and/or prognosis of events which are disadvantageous to patients or individuals in which important genetic and/or epigenetic parameters within genes associated with DNA replication said parameters obtained by means of the present invention may be compared to another set of genetic and/or epigenetic parameters, the differences serving as the basis for a diagnosis and/or prognosis of events which are disadvantageous to patients or individuals.

In the context of the present invention the term "hybridization" is to be understood as a bond of an oligonucleotide to a completely complementary sequence along the lines of the Watson-Crick base pairings in the sample DNA, forming a duplex structure. To be understood by

"stringent hybridization conditions" are those conditions in which a hybridization is carried out at 60°C in 2.5 x SSC buffer, followed by several washing steps at 37°C in a low buffer concentration, and remains stable.

The term "functional variants" denotes all DNA sequences which are complementary to a DNA sequence, and which hybridize to the reference sequence under stringent conditions and have an activity similar to the corresponding polypeptide according to the present invention.

In the context of the present invention, "genetic parameters" are mutations and polymorphisms of genes associated with DNA replication and sequences further required for their regulation. To be designated as mutations are, in particular, insertions, deletions, point mutations, inversions and polymorphisms and, particularly preferred, SNPs (single nucleotide polymorphisms).

In the context of the present invention, "epigenetic parameters" are, in particular, cytosine methylations and further chemical modifications of DNA bases of genes associated with DNA replication and sequences further required for their regulation. Further epigenetic parameters include, for example, the acetylation of histones which, however, cannot be directly analyzed using the described method but which, in turn, correlates with the DNA methylation.

In the following, the present invention will be explained in greater detail on the basis of the sequences and examples with reference to the accompanying figure without being limited thereto.

Figure 1

Figure 1 shows the hybridisation of fluorescent labelled amplificates to a surface bound olignonucleotide. Sample I being from an oligodendroglyome grade II tumour sample and sample II being from astrocytoma grade II cerebrum tissue. Flourescence at a spot shows hybridisation of the amplificate to the olignonucleotide. Hybridisation to a CG olignonucleotide denotes methylation at the cytosine position being analysed, hybridisation to a TG olignonucleotide denotes no methylation at the cytosine position being analysed.

Seq ID Nos. 1 to 94

Sequences having odd sequence numbers (e.g., Seq. ID No. 1, 3, 5, ...) exhibit in each case sequences of the chemically pretreated genomic DNAs of different genes associated with DNA replication.Sequences having even sequence numbers (e.g., Seq. ID No. 2, 4, 6, ...) exhibit in each case the sequences of the chemically pretreated genomic DNAs of genes associated with DNA replication which are complementary to the preceeding sequences (e.g., the complementary sequence to Seq. ID No.1 is Seq. ID No.2, the complementary sequence to Seq. ID No.3 is Seq. ID No.4, etc.)

Seq ID Nos. 95 to 98

Seq ID Nos. 95 to 98 show the sequences of oligonucleotides used in Example 1.

The following example relates to a fragment of a gene associated with DNA replication, in this case, MLH1 in which a specific CG-position is analyzed for its methylation status.

**Example 1:Methylation analysis in the gene MLH1 associated with DNA replication.**
The following example relates to a fragment of the gene MLH1 in which a specific CG-position is to be analyzed for methylation.

In the first step, a genomic sequence is treated using bisulfite (hydrogen sulfite, disulfite) in such a manner that all cytosines which are not methylated at the 5-position of the base are modified in such a manner that a different base is substituted with regard to the base pairing behavior while the cytosines methylated at the 5-position remain unchanged.

If bisulfite solution is used for the reaction, then an addition takes place at the non-methylated cytosine bases. Moreover, a denaturating reagent or solvent as well as a radical interceptor must be present. A subsequent alkaline hydrolysis then gives rise to the conversion of non-methylated cytosine nucleobases to uracil. The chemically converted DNA (sequence ID 31) is then used for the detection of methylated cytosines. In the second method step, the treated DNA sample is diluted with water or an aqueous solution. Preferably, the DNA is subsequently desulfonated (10-30 min, 90-100 °C) at an alkaline pH value. In the third step of the method, the DNA sample is amplified in a polymerase chain reaction, preferably using a heat-resistant DNA polymerase. In the present case, cytosines of the gene MLH1 are analyzed. To this end, a defined fragment having a length of 866 bp is amplified with the specific primer

oligonucleotides TTTAAGGTAAGAGAATAGGT (Sequence ID No. 95) and AAACAACTTAAATACCAATC (Sequence ID No. 96). This amplificate serves as a sample which hybridizes to an oligonucleotide previously bonded to a solid phase, forming a duplex structure, for example GGTTTGTACGAGTAGTTT (Sequence ID No. 97), the cytosine to be detected being located at position 135 of the amplificate. The detection of the hybridization product is based on Cy3 and Cy5 fluorescently labeled primer oligonucleotides which have been used for the amplification. A hybridization reaction of the amplified DNA with the oligonucleotide takes place only if a methylated cytosine was present at this location in the bisulfite-treated DNA. Thus, the methylation status of the specific cytosine to be analyzed is inferred from the hybridization product.

In order to verify the methylation status of the position, a sample of the amplificate is further hybridized to another oligonucleotide previously bonded to a solid phase. Said olignonucleotide is identical to the oligonucleotide previously used to analyze the methylation status of the sample, with the exception of the position in question. At the position to be analysed said oligonucleotide comprises a thymine base as opposed to a cytosine base i.e GGTTTGTATGAGTAGTTT (Sequence ID No. 98). Therefore, the hybridisation reaction only takes place if an unmethylated cytosine was present at the position to be analysed. The procedure was carried out on cell samples from 2 patients, sample I being from an oligodendroglyome grade II tumour sample and sample II being from a astrocytoma grade II cerebrum tumor sample.

From the results (Figure 1) it can be seen that the sample I contained contained only unmethylated cells at position 135 of the amplificate whereas sample II contained a mixture of methylated and unmethylated cells at position 135 of the amplificate.

**Example 2: Diagnosis of diseases associated with DNA replication**

In order to relate the methylation patterns to one of the diseases associated with DNA replication, it is initially required to analyze the DNA methylation patterns of a group of diseased and of a group of healthy patients. These analyses are carried out, for example, analogously to Example 1. The results obtained in this manner are stored in a database and the CpG dinucleotides which are methylated differently between the two groups are identified. This can be carried out by determining individual CpG methylation rates as can be done, for example, in a

relatively imprecise manner, by sequencing or else, in a very precise manner, by a methylation-sensitive "primer extension reaction". It is also possible for the entire methylation status to be analyzed simultaneously, and for the patterns to be compared, for example, by clustering analyses which can be carried out, for example, by a computer.

Subsequently, it is possible to allocate the examined patients to a specific therapy group and to treat these patients selectively with an individualized therapy.

Example 2 can be carried out, for example, for the following diseases:
Ataxia telangiectasia, ATR-X, Bloom's syndrome, neurological disorders, solid tumours and cancer

Table 1

Listing of particularly preferred genes of the present invention associated with the DNA replication

| *Gene* | *Database Entry No. (Genbank, internet address www.ncbi.nlm.nih.gov)* |
|---|---|
| CENPB | X05299 |
| DNA2L | D42046 |
| ATR | NM_001184 |
| CHD1L | NM_004284 |
| ERCC3 | NM_000122 |
| SNRPA1 | NM_003090 |
| RAD50 | NM_005732 |
| LIG2 | |

## Claims

1. A nucleic acid comprising a sequence at least 18 bases in length of a segment of the chemically pretreated DNA of genes associated with DNA replication according to one of the sequences taken from the group of Seq. ID No.1 to Seq. ID No.94 and sequences complementary thereto.

2. A nucleic acid comprising a sequence at least 18 base pairs in length of a segment of the chemically pretreated DNA of genes associated with DNA replication according to one of the sequences according to one of the genes CENPB (X05299), DNA2L (D42046),ATR (NM_001184), CHD1L (NM_004284), ERCC3 (NM_000122), SNRPA1 (NM_003090), RAD50 (NM_005732), LIG2 and sequences complementary thereto.

3. An oligomer, in particular an oligonucleotide or peptide nucleic acid (PNA)-oligomer, said oligomer comprising in each case at least one base sequence having a length of at least 9 nucleotides which hybridizes to or is identical to a chemically pretreated DNA of genes associated with DNA replication according to one of the Seq ID Nos. 1 to 94 according to claim 1 or to a chemically pretreated DNA of genes according to claim 2 and sequences complementary thereto.

4. The oligomer as recited in Claim 3; wherein the base sequence includes at least one CpG dinucleotide.

5. The oligomer as recited in Claim 3; characterized in that the cytosine of the CpG dinucleotide is located approximately in the middle third of the oligomer.

6. A set of oligomers, comprising at least two oligomers according to any of claims 3 to 5.

7. A set of oligomers as recited in Claim 6, comprising oligomers for detecting the methylation state of all CpG dinucleotides within one of the sequences according to Seq. ID Nos. 1 through 94 according to claim 1 or a chemically pretreated DNA of genes according to claim 2, and sequences complementary thereto.

8. A set of at least two oligonucleotides as recited in Claim 3, which can be used as primer oligonucleotides for the amplification of DNA sequences of one of Seq. ID No. 1 through Seq. ID No. 94 and sequences complementary thereto and/or sequences of a chemically pretreated DNA of genes according to claim 2, and sequences complementary thereto and segments thereof.

9. A set of oligonucleotides as recited in Claim 8,characterized in that at least one oligonucleotide is bound to a solid phase.

10. Use of a set of oligomer probes comprising at least ten of the oligomers according to any of claims 6 through 9 for detecting the cytosine methylation state and/or single nucleotide polymorphisms (SNPs) in a chemically pretreated genomic DNA according to claim 1 or a chemically pretreated DNA of genes according to claim 2.

11. A method for manufacturing an arrangement of different oligomers (array) fixed to a carrier material for analyzing diseases associated with the methylation state of the CpG dinucleotides of one of the Seq. ID No. 1 through Seq. ID No. 94 and sequences complementary thereto and/or chemically pretreated DNA of genes according to claim 2, wherein at least one oligomer according to any of the claims 3 through 5 is coupled to a solid phase.

12. An arrangement of different oligomers (array) obtainable according to claim 11.

13. An array of different oligonucleotide- and/or PNA-oligomer sequences as recited in Claim 12, characterized in that these are arranged on a plane solid phase in the form of a rectangular or hexagonal lattice.

14. The array as recited in any of the Claims 12 or 13, characterized in that the solid phase surface is composed of silicon, glass, polystyrene, aluminium, steel, iron, copper, nickel, silver, or gold.

15. A DNA- and/or PNA-array for analyzing diseases associated with the methylation state of genes, comprising at least one nucleic acid according to one of the preceeding claims.

16. A method for ascertaining genetic and/or epigenetic parameters for the diagnosis and/or therapy of existing diseases or the predisposition to specific diseases by analyzing cytosine methylations, characterized in that the following steps are carried out:

a) in a genomic DNA sample, cytosine bases which are unmethylated at the 5-position are converted, by chemical treatment, to uracil or another base which is dissimilar to cytosine in terms of hybridization behavior;

b) fragments of the chemically pretreated genomic DNA are amplified using sets of primer oligonucleotides according to Claim 8 or 9 and a polymerase, the amplificates carrying a detectable label;

c) Amplificates are hybridized to a set of oligonucleotides and/or PNA probes according to the Claims 6 and 7, or else to an array according to one of the Claims 12 through 15;

d) the hybridized amplificates are subsequently detected.

17. The method as recited in Claim 16, characterized in that the chemical treatment is carried out by means of a solution of a bisulfite, hydrogen sulfite or disulfite.

18. The method as recited in one of the Claims 16 or 17, characterized in that more than ten different fragments having a length of 100 - 2000 base pairs are amplified.

19. The method as recited in one of the Claims 16 through 18, characterized in that the amplification of several DNA segments is carried out in one reaction vessel.

20. The method as recited in one of the Claims 16 through 19, characterized in that the polymerase is a heat-resistant DNA polymerase.

21. The method as recited in Claim 20, characterized in that the amplification is carried out by means of the polymerase chain reaction (PCR).

22. The method as recited in one of the Claims 16 through 21, characterized in that the labels of the amplificates are fluorescence labels.

23. The method as recited in one of the Claims 16 through 21, characterized in that the labels of the amplificates are radionuclides.

24. The method as recited in one of the Claims 16 through 21, characterized in that the labels of the amplificates are detachable molecule fragments having a typical mass which are detected in a mass spectrometer.

25. The method as recited in one of the Claims 16 through 21, characterized in that the amplificates or fragments of the amplificates are detected in the mass spectrometer.

26. The method as recited in one of the Claims 24 and/or 25, characterized in that the produced fragments have a single positive or negative net charge for better detectability in the mass spectrometer

27. The method as recited in one of the Claims 24 through 26, characterized in that detection is carried out and visualized by means of matrix assisted laser desorption/ionization mass spectrometry (MALDI) or using electron spray mass spectrometry (ESI).

28. The method as recited in one of the Claims 16 through 27, characterized in that the genomic DNA is obtained from cells or cellular components which contain DNA, sources of DNA comprising, for example, cell lines, biopsies, blood, sputum, stool, urine, cerebral-spinal fluid, tissue embedded in paraffin such as tissue from eyes, intestine, kidney, brain, heart, prostate, lung, breast or liver, histologic object slides, and all possible combinations thereof.

29. A kit comprising a bisulfite (= disulfite, hydrogen sulfite) reagent as well as oligonucleotides and/or PNA-oligomers according to one of the Claims 3 through 5.

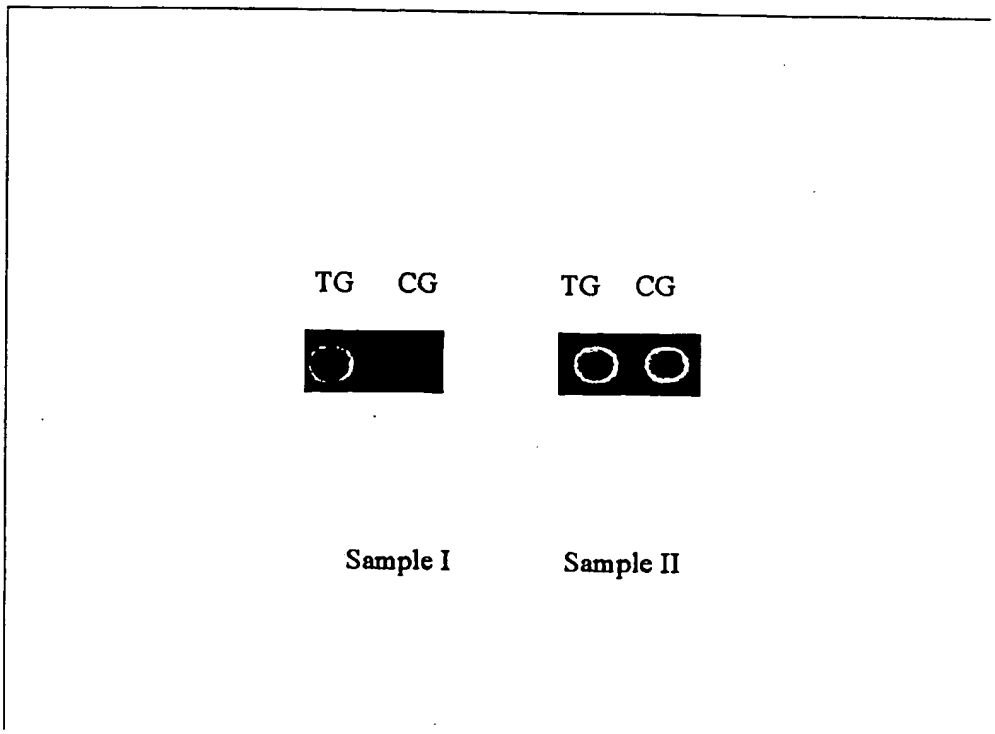
30. The use of a nucleic acid according to Claims 1 or 2, of an oligonucleotide or PNA-oligomer according to one of the Claims 3 through 5, of a kit according to Claim 29, of an array according to one of the Claims 12 through 15, of a set of oligonucleotides according to

one of claims 6 through 9 for the diagnosis of Ataxia telangiectasia, ATR-X, Bloom's syndrome, neurological disorders, solid tumours and cancer

31. The use of a nucleic acid according to Claims 1 or 2, of an oligonucleotide or PNA-oligomer according to one of Claims 3 through 5, of a kit according to Claim 29, of an array according to one of the Claims 12 through 15, of a set of oligonucleotides according to one of calims 6 through 9 for the therapy of Ataxia telangiectasia, ATR-X, Bloom's syndrome, neurological disorders, solid tumours and cancer

32. A kit, comprising a bisulfite (= disulfite, hydrogen sulfite) reagent as well as oligonucleotides and/or PNA-oligomers according to one of claims 3 through 5.

# Figure 1



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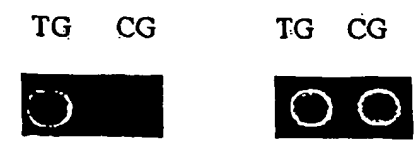
(54) Title: DIAGNOSIS OF DISEASES ASSOCIATED WITH DNA REPLICATION

(57) Abstract: The present invention relates to the chemically modified genomic sequences of genes associated with DNA replication, to oligonucleotides and/or PNA-oligomers for detecting the cytosine methylation state of genes associated with DNA replication which are directed against the sequence, as well as to a method for ascertaining genetic and/or epigenetic parameters of genes associated with DNA replication.




Sample I Sample II

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(74) Agents: SCHOHE, Stefan et al.; Boehmert & Boehmert, Pettenkoferstrasse 20-22, 80336 München (DE).

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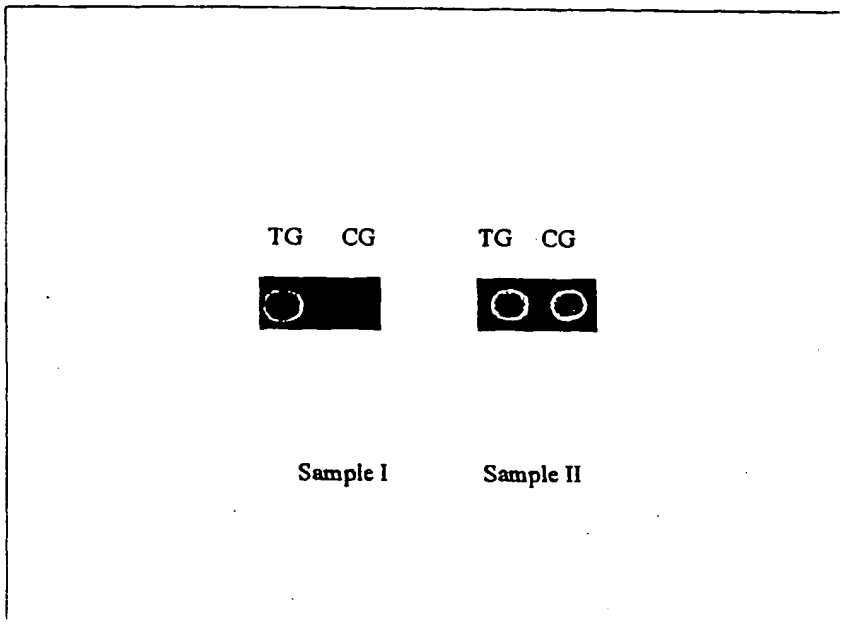
*[Continued on next page]*

(54) Title: DIAGNOSIS OF DISEASES ASSOCIATED WITH DNA REPLICATION BY ASSESSING DNA METHYLATION




(57) Abstract: The present invention relates to the chemically modified genomic sequences of genes associated with DNA replication, to oligonucleotides and/or PNA-oligomers for detecting the cytosine methylation state of genes associated with DNA replication which are directed against the sequence, as well as to a method for ascertaining genetic and/or epigenetic parameters of genes associated with DNA replication.

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, BIOSIS, MEDLINE, EMBL, EMBASE, CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | DATABASE GENBANK [Online]<br>NCBI; 10 January 1995 (1995-01-10)<br>PURANAM, K.L., ET AL.: "Homo sapiens (clone 1311) DNA helicase (REQL) mRNA, complete cds."<br>retrieved from HTTP://WWW.NCBI.NLM.NIH.GOV<br>Database accession no. L36140<br>XP002180958<br>the whole document | 1 |
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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19

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| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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| Y | | 9-32 |
| | --- | |
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19

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | DATABASE EMBL [Online]<br>EBI; 10 October 1995 (1995-10-10)<br>OGURA T.:: "NAD+ ADP-ribosyltransferase; PADPRP-I gene, promoter"<br>retrieved from<br>HTTP://WWW.EBI.AC.UK/CGI-BIN/EMBLFETCH<br>Database accession no. x16674<br>XP002190213<br>the whole document | 1,29,30 |
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| Y | | 6-29,32 |
| | --- | |
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| Y | | 3-29,32 |
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| Y | | 3-29,32 |
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| Y | | 3-29,32 |
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19

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | DATABASE EMBL [Online]<br>EBI; 9 March 1996 (1996-03-09)<br>IMAI T: "Homo sapiens ATM gene exon 1 and NPAT gene exon 1"<br>retrieved from<br>HTTP://WWW.EBI.AC.UK/CGI-BIN/EMBLFETCH<br>Database accession no. D83244<br>XP002190217<br>the whole document | 1,30,31 |
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| Y | | 7-32 |
| X | -& IMAI T ET AL.: "The structure and organisation of the human NPAT gene"<br>GENOMICS,<br>vol. 42, 1997, pages 388-392, XP002190209<br>figure F<br>table 2 | 3-6 |
| Y | --- | 7-32 |
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| Y | | 3-29,32 |
| X | -& BYRD P J ET AL.: "Mutations revealed by sequencing the 5' half of the gene for ataxia telangiectasia"<br>HUMAN MOLECULAR GENETICS,<br>vol. 5, no. 1, 1996, pages 145-149, XP002190210<br>page 147, right-hand column, paragraph 3 -page 148, right-hand column, paragraph 3<br>figure 2 | 1,3-6, 30,31 |
| Y | --- | 7-29,32 |
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19

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

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19

# INTERNATIONAL SEARCH REPORT

Im ıtional application No.
PCT/EP 01/03971

**Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

Although claim 31 is directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

As a result of the prior review under R. 40.2(e) PCT, no additional fees are to be refunded.

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [X] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

1,3-32(all part.) corresponding to inventions 1-6

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

[X] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: part.: 1,3-32

Invention 1:

A nucleic acid comprising a segment of chemically pretreated DNA of a gene associated with DNA replication according to sequence SEQ ID NO.1 or 2, oligonucleotides having a sequence of at least 9 nucleotides identical or hybridizing to said DNA; a set of said oligonucleotides; the use of said set for detecting SNPs or the methylation state of cytosines in said nucleic acid; an array or set of said oligonucleotides fixed to a carrier; a method of producing said array; a method for diagnosis and/or therapy of diseases or disease predispostion using said oligonucleotides by analysing cytosine methylations; a kit comprising said oligonucleotides and bisulfite; and the use of said nucleic acid, oligonucleotides, set of oligonucleotides, array or kit for the diagnosis or therapy of diseases.

2. Claims: part.: 1,3-32

Invention 2:

A nucleic acid comprising a segment of chemically pretreated DNA of a gene associated with DNA replication according to sequence SEQ ID NO.3 or 4, oligonucleotides having a sequence of at least 9 nucleotides identical or hybridizing to said DNA; a set of said oligonucleotides; the use of said set for detecting SNPs or the methylation state of cytosines in said nucleic acid; an array or set of said oligonucleotides fixed to a carrier; a method of producing said array; a method for diagnosis and/or therapy of diseases or disease predispostion using said oligonucleotides by analysing cytosine methylations; a kit comprising said oligonucleotides and bisulfite; and the use of said nucleic acid, oligonucleotides, set of oligonucleotides, array or kit for the diagnosis or therapy of diseases.

3. Claims: part.: 1,3-32

Invention 3:

A nucleic acid comprising a segment of chemically pretreated DNA of a gene associated with DNA replication according to sequence SEQ ID NO.5 or 6, oligonucleotides having a sequence of at least 9 nucleotides identical or hybridizing to said DNA; a set of said oligonucleotides; the use of said set for detecting SNPs or the methylation state of cytosines

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

in said nucleic acid; an array or set of said oligonucleotides fixed to a carrier; a method of producing said array; a method for diagnosis and/or therapy of diseases or disease predispostion using said oligonucleotides by analysing cytosine methylations; a kit comprising said oligonucleotides and bisulfite; and the use of said nucleic acid, oligonucleotides, set of oligonucleotides, array or kit for the diagnosis or therapy of diseases.

The same grouping applies to SEQ ID NOs.7-94 giving inventions 4-47.

48 4. Claims: part.: 2-32

Invention 48:

A nucleic acid comprising a segment of chemically pretreated DNA of the gene CENPB associated with DNA replication, oligonucleotides having a sequence of at least 9 nucleotides identical or hybridizing to said DNA; a set of said oligonucleotides; the use of said set for detecting SNPs or the methylation state of cytosines in said nucleic acid; an array or set of said oligonucleotides fixed to a carrier; a method of producing said array; a method for diagnosis and/or therapy of diseases or disease predispostion using said oligonucleotides by analysing ctosine methylations; a kit comprising said oligonucleotides and bisulfite; and the use of said nucleic acid, oligonucleotides, set of oligonucleotides, array or kit for the diagnosis or therapy of diseases.

The same grouping applies to the genes: DNA2L, ATR, CHD1L, ERCC3, SNRPA1, RAD50, and LIG2 giving inventions 49-55.

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